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GROUND WATER UTILIZATION:
STUDY OF METHODS, WITH ENGINEERING ANALYSIS (U)
(INTERIM TECHNICAL REPORT)

BY
DR. A. B. RUDAVSKY
AUGUST 1969

PREPARED FOR:
U. S. ARMY MOBILITY EQUIPMENT RESEARCH AND DEVELOPMENT CENTER
FORT BELVOIR, VIRGINIA 22060

PROJECT NO. HRS-021-69

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Report No. DAAK02-69-C-0786-I

GROUND WATER UTILIZATION:
STUDY OF METHODS, WITH ENGINEERING ANALYSIS (U)
(INTERIM TECHNICAL REPORT)

DA PROJECT 62141011 1J662708D565 Water Supply Technology
DA TASK 62141011 1J662708D565 01 Ground Water Studies
WORK UNIT 62141011 1J662708D565 01 017

By
Dr. A. B. Rudavsky
August 1969

Prepared For:
U.S. ARMY MOBILITY EQUIPMENT RESEARCH AND DEVELOPMENT CENTER
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SUMMARY

The objective of this report, under the contract, is to summarize all known well construction techniques for obtaining ground water during military field operations and to recommend those methods deemed most suitable, in the judgment of Hydro Research Science, to the required application.

The study, to achieve this objective, comprises six phases:

1. Library research
2. Detailed investigations of limiting parameters
3. Analysis of existing techniques
4. Resolution of most effective methods
5. Review and evaluation of available hardware
6. Conclusions and recommendations.

The material in the phase of work presented in this interim report covered mostly library research, evaluation, and categorization of data. This phase was principally a library research effort, but also included contact with manufacturers of well drilling and related equipment. A bibliography of 730 library sources was compiled. Three hundred fifty will be evaluated. Two hundred ninety five companies were contacted and meetings have been set up with the most promising companies producing equipment within the specifications of the contract. In compilation of the bibliography, standard indexes and abstracts were used; libraries were utilized in the local area, as well as specialized libraries contacted in the United States.

Conclusions derived from this study at the present time are that commercially available equipment is not applicable to the specified hardware required by the contract. Several arrangements could possibly be applied after modifications, and this will be the object of research in the remaining part of the contract. A review of the novel drilling techniques shows a majority of them to be in an academic stage and not worthwhile pursuing on a commercial market.

Future work will be concentrated, for the most part, in evaluating the data obtained in library research, as well as evaluation of the commercially available drilling equipment and its adaptability, miniaturization, or changes to meet the specifications of the U. S. Army.

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FOREWORD

This project was performed by Hydro Research Science, Sunnyvale, California, by authorization of the U. S. Army Mobility Equipment Research and Development Center, Fort Belvoir, Virginia, under Contract DAAK02-69-C-0786, 30 June 1969. The work was performed under DA Project 62141011 1J662708D565 Water Supply Technology, DA Task 62141011 1J662708D565 01 Ground Water Studies, Work Unit 62141011 1J662708D565 01 017.

The effort includes both library research and manufacturer contact. The data accumulated will provide the basis for a thorough evaluation and assessment of well drilling equipment for military utilization.

This project was directed by Dr. A. B. Rudavsky and conducted by the staff of Hydro Research Science.

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INTRODUCTION

The objective of this study is to provide technical research and engineering evaluation in the development of a comprehensive report on methods of exploiting ground water for military field operations. This study, when compiled, will summarize all known techniques for obtaining ground water during military field operations and will recommend those methods deemed most suitable for tactical use.

This study is principally a library research effort and a review of well drilling methods and related equipment through contact with manufacturers and their research and development departments. This study comprises six distinct phases:

1. Library research and contact with manufacturers
2. Detailed investigation of limiting parameters
3. Analysis of existing techniques
4. Resolution of most effective method(s)
5. Review and evaluation of available hardware
6. Conclusions and recommendations.

This report covers an effort that was directed toward the preparation of a selected bibliography and the compilation and partial review of the existing literature relating to ground water exploitation for military use. It also included a compilation of catalogs, pamphlets, and other descriptive materials for the off-shelf items of well drilling and related equipment, and exploration of the status of industry's research and development of this equipment. In terms of the six phases specified above, library research and manufacturer contact is approximately 90% complete. The detailed investigation of limiting parameters and analysis of existing techniques are phases which are partially complete and being explored fully at the present time. This report covers the time period from July 1, 1969 to August 31, 1969 and primarily comprises the selected bibliography compiled for the execution and completion of this study.

DISCUSSION OF RESEARCH

GENERAL

Potable water is of major importance for prosecution of U. S. Army field operations. At present, of the two resources, ground water and surface water, the latter is primarily used in tactical operations, since it is easily available and purification techniques have been perfected. Ground water, despite its superior sanitary quality, has not yet been exploited for field operations because the available well drilling equipment is excessively heavy and bulky, time consuming to erect and operate, difficult to camouflage, and requires a high degree of operator skill.

OBJECTIVE

The objective of this study is to provide technical research and engineering evaluation in the development of a comprehensive report on methods of exploiting ground water for tactical military use. This study reviews the present methods of well construction, evaluates new drilling techniques for possible application to military use and, on the basis of this review, will recommend a method or methods to meet U. S. Army field operation objectives. The basis for such a study must be a thorough library research.

LIBRARY RESEARCH

Library research involved compilation of selected bibliography obtained from a search of multi-lingual literature obtained from indexes and other library resources. Seven hundred thirty references have been compiled; most of them annotated and cataloged on cards.

In compilation, the following indexes and abstracts were consulted: Applied Science and Technology Index, Engineering Index, Library of Congress Catalog of Printed Cards, Geodex, Polish Technical Abstracts, British Technology Index, Petroleum Abstracts, Bibliography of Bibliographies, Agriculture Index, Index of Geology, Geo-Science Abstracts, Monthly Catalog of U. S. Government Publications, National Petroleum Bibliography, Applied Mechanics Review, Chemical Abstracts, Readers' Guide to Periodical Literature, Cumulative Book Index, Water Pollution Abstracts, and Monthly Index of Russian Accessions.

Three libraries have been used extensively in obtaining the references: San Jose State Library, Stanford University Library, and the University of California Library in Berkeley. The branch libraries of Branner Geological, Engineering, Physics, and Government Documents at Stanford University, and the branch libraries of Engineering, Earth Science, Agriculture, and Water Resources Archives of the University of California, Berkeley, were used extensively and were helpful in compiling the material. The following additional libraries were consulted either by visiting them directly or by correspondence: Department of the Interior Library, Washington, D. C.; Geological Survey Library, Washington, D. C.; Geological Survey Library, Menlo Park, California; Library of Congress, Science and Technology Division, Washington, D. C.; U. S. Army Library, Pentagon, Washington, D. C.; Bureau of Reclamation Library, Sacramento Branch, California; Bureau of Reclamation Library, Denver, Colorado; Research Center Library, Waterways Experiment Station, Vicksburg, Mississippi; Sacramento State Library, Sacramento, California; Engineering Societies Library, United Engineering Center, New York; NASA Science and Technology Reference System, College Park, Maryland; and Defense Documentation Center, Cameron Station, Virginia. The search covered books, journals, institutional publications, government reports, research reports, and other publications. These were reviewed up through August, 1939. Generally, the period from 1940 to the present was covered except for some older sources which apply.

The papers listed in the Selected Bibliography were ordered, as far as possible, by date of publication, and reviewed sequentially, beginning with the earliest and proceeding to the most recent. Specific items of interest of each paper were abstracted and material placed into major subdivisions for evaluation in the final report.

CONTACT WITH MANUFACTURERS

Manufacturers of well drilling and related equipment were contacted and their literature solicited. Catalogs, pamphlets, descriptive literature, and leaflets were compiled according to the three major types of well construction: percussion drilling, rotary drilling, and earth boring. The material, after classification, was compiled in charts (to be reproduced in the final report) according to the variables of interest. A sequence of meetings was scheduled with companys whose products looked promising for further

exploration. Miniaturization and re-adaptation for military use of their respective equipment is and will be discussed. The discussions are monitored on tape and transcribed, so that a written record is available.

PRESENT RESEARCH

Having assembled the library material, the major efforts at the present time are concentrated on grouping, compiling, and evaluating the abstracted material. The academic, as well as the practical aspects, are evaluated by both a PhD and an experienced well driller. It was found that the most convenient and expedient manner was to segregate the abstracted literature, as well as the industrial equipment material, into three major groupings:

1. Conventional well construction methods
2. Novel and improved drilling techniques
3. Well construction equipment

CONVENTIONAL WELL CONSTRUCTION METHODS

The well construction methods used by the U. S. Army for well drilling operations are summarized in the Department of the Army Technical Manual TM5-297. Classifications from this manual were used and expanded upon for review and analysis of the material compiled by the library on conventional well construction methods. These conventional methods encompass dug, bored, driven, jetted, and drilled wells. The latter is subdivided into rotary and percussion methods, which are further subdivided according to five fundamental operations of well construction: (1) drilling operation, (2) installing the casing, (3) installing the well screens, (4) providing for sanitary protection, and (5) developing the well. Each of these well construction techniques is scrutinized in terms of the enumerated Army tactical requirements as to weight, size, assemblage, transportability, mobility, camouflagability, and ease of operation. The pertinent data on characteristics of the various equipment are being tabularized in charts and their limits and limitations compared.

The partial review of the compiled material indicates that the standard commercially produced well drilling equipment

is too heavy and too bulky to meet the hardware requirements specified by the Army. On the other hand, some newly developed compact core drilling equipment seems to hold promise when properly evaluated and possibly re-adapted to military use.

NOVEL AND IMPROVED DRILLING TECHNIQUES

The partial review of the literature compiled on novel and improved drilling techniques indicates that considerable effort was expended by academic and petroleum industrial research throughout the world during the last three decades on drilling techniques and systems. Research was generally conducted by the petroleum industry because of their larger financial resources; however, the water well industry will benefit greatly from these developments.

The novel techniques are being reviewed and examined with great care, despite the fact that they may not appear economically feasible at the present time. Should one of these methods show qualities superior to presently used techniques, further research and development would be justified for successful application for military operations.

This partial review of the compiled material indicates two distinct groupings of research effort by industry and academic institutions: (1) cost reduction efforts through improvements of the presently used equipment and techniques, (2) experimentation with novel, exotic, and other promising drilling methods. Some of these techniques are defined only in concepts, some have passed the laboratory stage, and some have even been tested in the field. The efforts in the first group involved evaluation of the most effective impact frequencies, the range of economically efficient rotational speeds, effective actuation of percussors, the power delivery, transmission and output of the drills, etc. All of these efforts in an overall view concentrate fundamentally on improvement of the rock destruction technique through impact or abrasion, or in streamlining or accelerating drilling operations.

Considerable research is being done and experience gained in down-hole prime mover drilling, especially using turbo-drills. On the latter drilling method, which is one of the standard methods in Russia, considerable technical literature is available and will be evaluated for the final report.

The partial review of the novel drilling techniques indicates that some have passed the exploratory stage and are seriously considered for effective employment in industry (for example, the shock wave drill or the use of explosives).

All these developments are being classified and incorporated for final compilation into a report with ten groupings as originally proposed by the U. S. Army: (1) improved rotary drilling, (2) hollow auger drilling, (3) improved percussion drilling, (4) downhole prime mover drilling, (5) rock melting, (6) rock spallation, (7) ultrasonic decrepitation, (8) shape-charge disintegration, (9) propellant driving, and (10) other methods not included above.

WELL CONSTRUCTION EQUIPMENT

By considering the previous five fundamental well construction operations and the classification of well types, well construction equipment can be classified into the following initial equipment groupings: (1) percussive drilling tools, (2) rotary drilling tools, (3) percussive equipment, (4) rotary equipment, (5) cables, connectors, etc., (6) casings, (7) screen wells, (8) augers, (9) derricks, (10) pumps, and (11) power sources. Equipment used in well construction can, in some cases, be interchanged or readapted by minor changes to a different technique. A review of the various equipment components, their interchangeability and evaluation of limitations of each component can result in obtaining an equipment combination which will be best suited for Army requirements. The data will be compiled in tabular comparative arrangement.

PROGRAM FOR FINAL REPORTING PERIOD

The program for the final reporting period encompasses locating the last of the hard-to-find references within the library research phase, completion of identifying the limiting parameters within the scope of the investigation, and finishing the analysis of existing techniques. The review will indicate the most promising and effective methods and these will be studied in depth with the final recommendations and conclusions specified in the report. The remaining time will be devoted to compilation of the report with an organized presentation of the accumulated data.

CONCLUSIONS

The almost completed library research and compilation of selected bibliography shows that a considerable number of references on drilling methods and equipment exist in multi-language literature. Many of these references refer to novel, unorthodox, and exotic drilling methods, some of them in the academic stage, others proven through laboratory and field tests. The literature study shows considerable completed research for developing bottom hole drilling methods. The conventional application of turbodrills in Russia is documented by the extensive technical literature on this subject in this language. The literature further indicates that considerable efforts have also been spent to improve present drilling tools and systems in order to reduce drilling costs.

The review of manufacturer's catalogs, leaflets, descriptive literature, and other printed matter on off-shelf items for the well drilling industry indicates very few radical changes in drilling concepts but a trend of the industry to improve the drilling techniques and well construction. The partially completed review of well construction equipment and construction methods indicates a prevalence of heavy, cumbersome, and difficult-to-operate standard well equipment in commercial use which is objectionable for military tactical purposes.

The partial review of novel drilling techniques shows some to be exotic, some being tested only in laboratories, and some still in the realm of academic speculation. Several promising drilling methods appear not economically feasible for commercial production, but might be considered applicable for rock removal in military application.

RECOMMENDATIONS

The current investigations have indicated that the approach to the solution of the problem through thorough library research and thorough contact of well drilling and related equipment manufacturers is the most effective avenue to analyze the problem. The compilation of data in terms of conventional methods, equipment, and novel drilling techniques appears, on the basis of partial completion of some of the aspects of the study, to be the proper approach and will lead to an evaluation of the equipment meeting the U. S. Army standards. It is, therefore, recommended that the study be continued along the outline of Hydro Research Science's approach and be completed as indicated in this report.

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